PLAYFUL LEARNING IN ONLINE STEM USING ROBOTICS

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Approval

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Dedication

Dedicated to...

All the assiduous and hardworking people

All who portray sheer devotion and perseverance

All who remain resilient in the face of adversity

All who spread light in moments of darkness

Dedicated to all who...

Never Give Up

Certificate of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by any other person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at NUST SEECS or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST SEECS or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics which has been acknowledged.

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Abstract

Playful learning is an approach that uses play to support discovery learning and problem-solving. In an online learning environment that aims to teach STEM education, incorporating playful learning is a challenge especially during instances such as the COVID-19 lockdown. The purpose of this study is to overcome this challenge and explore the effectiveness of using playful techniques by incorporating elements of game design and robotics to teach STEM concepts in an online learning environment. This study investigates the effects of using playful learning in online STEM education on student engagement and effective learning.

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List of Abbreviations

STEM – Science Technology Engineering Maths

ER – Educational Robotics

SEG – Serious Educational Games

GBL – Game Based Learning

EDA – Exploratory Data Analysis

SPSS – Statistical Package for the Social Sciences

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1. Introduction

1.1. Background

STEM is a curriculum based on the idea of educating students in four specific disciplines: science, technology, engineering and mathematics — in an interdisciplinary and applied approach. Rather than teach the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications. The aim of STEM education is to train qualified individuals to meet 21st century workforce needs.

"STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros et al., 2009)."

Playful learning, also referred to as learning through play, is an approach that uses children's play to support discovery learning and problem-solving. In an online learning environment that aims to teach STEM education, incorporating playful learning is a challenge mainly because play is associated with hands on activities in a physical space whereas an online environment can only provide a virtual learning experience. The aim of this research is to overcome this challenge and explore factors that make STEM e-learning fun, engaging and effective, keeping the students intrinsically motivated.

Significant research is being carried out in the field of STEM, including role of robotics in STEM and integrating STEM in classrooms. However, little or no research is available on incorporating playful learning to teach STEM concepts using robotics in an online learning environment.

1.2. Motivation

"Generation Alpha" is considered the most technological-infused demographic up to date and needs to be taught and bred in an educational environment entirely different than what their predecessors experienced. Future workplace demands 21st Century skills, innovation and creativity. To achieve this purpose, students require an active learning environment in order to become expert learners. Pakistani students have massive potential but most lack access to an effective learning environment that can inculcate required skills and practical knowledge.

The COVID-19 pandemic has created the largest disruption of education systems in history, affecting nearly 1.6 billion learners in more than 190 countries and all continents (United Nations, 2020). Closures of schools has led to home schooling and e-learning in which creating an effective and engaging learning environment has been a major challenge. Moreover, in an online environment keeping learners intrinsically motivated is a demanding task. Imparting knowledge online in domains that require physical learning aids such as STEM has been very difficult in COVID.

We believe playful learning in online STEM will help create effective learning environments and benefit students. Learners will stay intrinsically motivated by learning through online play. It will prove to be a fine alternative to classroom education in learning crises such as the recent pandemic hit. The research will also pave way for future studies in online STEM domain. Furthermore, playful online learning can also be incorporated in schools to aid blended learning. Supervision, quality assurance and feedback in e-learning environment are also possible due to features such as recording lectures, data monitoring and tracking student performance.

COVID has disrupted classroom learning; hence the main motivation behind this research is to study the effectiveness of an online learning environment where students can

playfully learn STEM skills as it is essential in making Pakistani learners become innovators, scientists and makers of tomorrow.

1.3. Study Overview

The purpose of this study was to minimize the gaping hole in the research world by exploring the effectiveness of using playful techniques by incorporating robotics as a learning aid to teach STEM concepts online. It aimed at investigating the effects of using playful learning in online STEM on student engagement and effective learning.

The design framework implemented for this study describes the types of engagement created through game design elements to foster playful learning. For this research, we have focused on studying the impact of affective, cognitive, and physical engagements of students created by the inclusion of game design elements in a playful online learning environment to teach a STEM topic.

As this study was conducted online, elements of game design were implemented in the research by using a robotics website to attain playful learning. Students had to code their virtual robots through block-based programming and solve certain challenges, this helped incorporate the design framework as well as the STEM topic chosen for this study. This research was an attempt to compare playful pedagogy with traditional teaching methods in online learning during the lockdown period in COVID.

A quasi experimental study was conducted and non-equivalent control group post-test only design was employed for this research. Students of Grade 6 and 7 from Army Public Schools of Rawalpindi and Nowshera were chosen for the control and experimental groups with 50 participants in each group (total sample size N=100).

A significant difference in the means of both the groups was revealed when quantitative data analysis was performed. Therefore, it was concluded that using robotics and game design elements to implement playful learning results in enhanced engagement of students.

2. Literature Review

"We live in a world that is changing more rapidly than ever before. Today's children will face a continual stream of new issues and unexpected challenges in the future. Many things that they learn today will be obsolete tomorrow. To thrive, they must learn to design innovative solutions to the unexpected problems that will undoubtedly arise in their lives. Their success and satisfaction will be based on their ability to think and act creatively. Knowledge alone is not enough: they must learn how to use their knowledge creatively" (Resnick, 2014, p.13). In traditional school classrooms, it is observed that students who have short attention spans often display great concentration when engaged in projects that interest them. Seymour Papert has found that learners become deeply engaged by "hard fun". Simply put, learners do not mind activities that are difficult if the activities connect deeply with their interests and passions.

Evidence suggests that improved student engagement is a result of capturing students' attention, nurturing deep learning, and minimizing cognitive load ultimately leading to better educational outcomes (Mulqueeny et al., 2015).

In classrooms, teachers can use robotics activities to integrate STEM and incorporate 21st century skills, including creativity (Marghitu et al., 2012), collaboration, critical thinking (Freiman et al., 2010), computational thinking (Atmatzidou & Demetriadis, 2016; Keane et al., 2016), and communication skills (Prelock & Nelson, 2012).

2.1. Theoretical Framework

The robotics learning environment is strongly associated with two central learning theories that have been influencing science education since the mid-twentieth century: *constructivism* and *constructionism*. Constructivism is a theory about how people learn (Piaget, 1965). It suggests that learners construct knowledge out of their own experiences. Based on Piaget's theory of constructivism, Papert (1980) proposed the constructionism learning theory, according to which meaningful learning takes place when students construct real physical

objects that are meaningful to them and that they can share with others. Based on the philosophy of constructionism, tangible tools can be used to ‘think with’ in order to explore STEM concepts (Barker & Ansorge, 2007). The hands-on applications of STEM concepts help develop 21st century skills, as objects such as robots are constructed to explore and experiment with ideas (Mikropoulos & Bellou, 2013).

The theories of constructivism and constructionism offer a framework for developing a learning environment in which individuals learn by making, creating, programming, discovering and designing their own objects that allows them to think with. For example, teachers allowing kindergartners to play with Play-Doh to make objects meaningful to them can be an example of a constructivist approach. Whereas, students working collaboratively on a project to build a plant watering robot facilitated by their teacher could befit the constructionism learning theory.

Rob & Rob (2018) define the role of teacher and learning environments pertaining to both theories as follows:

Constructivist Teacher: A constructivist teacher sets up the environment that fosters individual learning for students and presents a problem to be solved, while the students go on their own way to produce a personally meaningful artefact without any further teacher’s intervention. The learning environment can be termed as teacher initiated.

Constructionist Teacher: A constructionist teacher sets up the environment for collaborative learning of students, then he or she defines the problem to be solved and the meaningful product to be developed, and then guides them to reach towards the goal. The learning environment can be termed as teacher facilitated.

Hence, we can associate the learning theories with the attributes outlined in Table 1.

Table 2.1: Constructivism vs Constructionism

Theories	Attributes			
	Experience	**Artifact**	**Collaboration**	**Use of Tools, Media and Context**
Constructivism	Knowledge is inherited from past experience Knowledge is constructed by new experience	Construct a Personal Artifact	Not necessary	Not necessary
Constructionism	Knowledge is inherited from past experience knowledge is constructed by new experience	Construct a Meaningful Artifact	Collaborative Creation Process Sharing of artifacts	Learning is enhanced by use of tools (computer, pen) Media (face to face or online classroom) and Context (real world product, educational goal)

Robotics, with its multi-disciplinary nature, provides constructive learning environments that are suitable for a better understanding of STEM subjects (Khanlari, 2014). Playful approaches in education sit within a constructivist theory of learning. This can also be associated to gamification of educational content and learning through games. Gamification has emerged as a common instructional intervention to improve learner motivation and learning outcomes.

According to Foreman, (2003, p.15), ‘‘Games expose players to deeply engaging, visually dynamic, rapidly paced, and highly gratifying pictorial experiences that make almost any sort of conventional schoolwork (especially when mediated by a lecture or text) seem boring by comparison.’’ The ability to take on multiple roles allows for the game player to gain multiple perspectives of a given scenario which facilitate richer construction of knowledge and

deep integration of content. Often referred to as ‘‘guided discovery’’, learners immersed in well-designed Serious Educational Games (SEGs) are able to monitor their own thinking (meta-cognition), gain new knowledge, and revise existing schemata.

2.2. Robotics in STEM

A review of relevant STEM education literature highlighted that students were more likely to participate in STEM activities if they had teachers who provided engaging STEM activities in the classroom (Hayden et al., 2011). Robotics has proven to be an engaging tool for motivating students to participate in STEM activities (Ludi, 2012). Robotics has also proven to be an effective tool to engage and stimulate teachers’ interest in STEM learning and teaching (Lee et al., 2014). Robotics-based professional development can assist teachers with developing skills in designing, constructing, and programming and with developing an understanding of how constructionist approaches to learning can enhance problem solving and higher-order thinking among their students.

Robotics activities provide great opportunities for students to learn important mathematics and science concepts—and learn them in a much more meaningful and motivating context than in traditional classrooms (Mitchel Resnick, 2004). Robotics can be especially effective in teaching STEM, as it enables real-world applications of the concepts of engineering and technology and helps to remove the abstractness of science and mathematics. In fact, various robotics activities led to improvements in science, technology, engineering, and/or mathematics learning (Kim et al., 2015). According to Karim (2016), Robots have the potential to be an effective add-on to traditional education. Robots bring excitement and the opportunity to experiment with tangible objects in classroom which is considered effective for learning.

ER4STEM was a project launched that aimed to realize use of educational robotics creatively to maintain children’s curiosity in the world. This would lead them to entrepreneurial, industrial and research careers in STEM fields, by exploiting the

multidisciplinary potential of robotics with a well-structured interdisciplinary approach (Lammer et al., 2017).

Robots spark the imagination of children and adults alike since they are relatable to humans in doing different tasks, this can be attributed as a reason to growing use of Educational robotics (ER). ER is often presented as a platform for teaching STEM, developing skills such as scientific inquiry, engineering design, problem solving, creative thinking and teamwork. ER enhances motivation and contributes to cooperation, confidence, and creativity. Therefore, ER applications also have a potential to improve classroom teaching (Kucuk & Sisman, 2020).

Robotics allows students to learn about STEM's interdisciplinary nature, encouraging students to work collaboratively (Yuen et al., 2014). In a study that examined elementary and middle school students' participation during a summer camp, robotics was found to be highly engaging (Yuen et al., 2014). Additionally, programming robots helps students to engage in science inquiry as described by Linn and Hsi (2000): (a) science is made accessible by engaging with physical models; (b) thinking is made visible through construction and design principles; (c) students learn from each other through collaboration; and (d) autonomous learning skills are developed through self-directed learning. Whether it is through the engaging process of constructing robots or the excitement of the competitions, several robotics programs have resulted in an increase in students' comfort level with applications of STEM, development of twenty-first-century skills, and increased interest in pursuing STEM-related programs beyond high school (Brand & Kinash, 2013; Grubbs, 2013; Hunter et al., 2006).

Physical robots can embody mathematical concepts allowing greater affective engagement. Virtual robotics facilitate the planning and modelling of physical robotics encouraging expression of symbolic mathematical language (Samuels & Haapasalo, 2012).

The interaction with robots increases motivation, engagement and attitude towards education. "Admittedly, with the simplification of robot design and assembly process; the

inclusion of intuitive visual drag and-drop programming and the gradually reducing cost of educational robot platforms, we are experiencing the advent of a new era in educational technology" (Karim et al., 2016)

2.2.1. Lego Robotics

Lego robotics is used as an authentic and kinesthetics way to improve children's problem-solving skills, reinforcing science applications and concepts, while building upon informal learning activities often done at home (Karp & Maloney, 2013).

Using Lego EV3 robotics builds spatial visualization skills as students manipulate Lego pieces to build the robot. Other mathematics skills include proportional reasoning as students calculate wheel rotation and approximate the distance the robot will travel once it is programmed (Grubbs, 2013). ''Not only does the design and hands-on component of technology stay intact, but students also enjoy solving a realistic engineering scenario, role playing…and constructing physical components through an open-ended design challenge'' (Grubbs, 2013, p.12).

Lego Mindstorms is a hardware and software structure which is produced by Lego for the development of programmable robots based on Lego building blocks. Research has found that introducing Technology with Lego Mindstorms to young kids is more effective than making them code early on. Even in children as young as 6 years old, Robotics with Lego is found effective to expose them to both the principles and ideas of coding, like logic, and elements of engineering through robotics. The small parts in Lego Mindstorms challenge younger students developing motor skills and coordination. (*Learning through Play with Lego Mindstorms – BSD Education*, n.d.)

2.2.2. Arduino Robotics

Arduino-based educational robotics can promote a collaborative development environment that helps to develop innovation and student motivation during the learning

process. When it comes to young learners, it is preferable to start from simple challenges and increase the difficulty gradually. The combination of theory and practice is important, linking fun tasks with challenges by applying theory to problem solving aids learning. Arduino is a tool to consider in this regard, since Arduino software is free and compatible with most operating systems (Plaza, Blazquez, et al., 2018).

Arduino is a software and hardware solution that requires greater skill on the part of students. This is because the programming is textual, and the hardware components used are not intended for use by young students. Despite this, Arduino allows applications to be implemented without any limitations (Plaza et al., 2019).

Some Arduino Robotics kits include Elegoo Smart Robot Car Kit, Makeblock Educational robot kit, Codibot, Arduino Robot etc.

2.2.3. Other Robotics kits

Apart from Arduino and Lego kits, there are other Robotics kits available as well that aim to teach STEM. Some of these include, “Robo bit buggy” based on micro:bit programmable controller. “GoPiGo 3” is a robot car based on Raspberry Pi. “Sunfounder PiCar” is also a kit on Raspberry Pi. “Cozmo” is a commercial robot that has a beginner-friendly interface and is deemed a great educational robot for kids and adults to learn to code creatively. “Meccano Meccaspider” robot kit comes with 291 building parts and can be controlled via Meccano educational app.

2.3. Online STEM environments

Web based applications promote learning in many ways overcoming the limitations of time and physical space. Owing to the need of media literacy as an essential 21st century skills, many online platforms provide the opportunity for online education. Some online environments focusing on STEM education are mentioned as follows:

- “VEXcode VR” lets you code a virtual robot using a block-based coding environment powered by Scratch Blocks.
- The “Open Roberta® Lab” is a freely available, cloud-based, open source programming environment that makes learning programming easy - from the first steps to programming intelligent robots with multiple sensors and capabilities.
- “simulator.io” is an online CAD tool for logic circuits. Easiest way to learn how to build logic circuits.
- “Tinkercad” is a free, online 3D modelling program that runs in a web browser, known for its simplicity and ease of use. Since it became available in 2011 it has become a popular platform for creating models for 3D printing as well as an entry-level introduction to constructive solid geometry in schools. Its add on, Tinkercad circuits allows wiring of basic electrical circuits as well as programming circuits integrated with Arduino and testing simulations of circuits.
- “BrainPop” is a group of educational websites with over 1,000 short animated movies for students in grades K-12, together with quizzes and related materials, covering the subjects of science, social studies, English, math, engineering and technology, health, and arts and music.

Two of the most popular and STEM focused online platforms are Scratch and Minecraft. For this thesis, these two platforms have been reviewed in detail and outlined in the headings below.

2.3.1. Scratch

Mitchel Resnick believes that in order to help young people prepare for a world that is changing more rapidly than ever before, it is important to embed making and coding in a creative-learning process characterized by Projects, Peers, Passion, and Play; namely the 4P’s which form the design principles of the Scratch learning environment.

With Scratch, young people can design their own interactive media including stories, games, animations, and simulations by attaching coding blocks together, “just as one might snap together LEGO bricks or puzzle pieces” (Brennan et al., 2009).

The Scratch programming environment and language provide users the opportunity to learn programming very quickly and it has variety to keep learners engaged for years (Maloney et al., 2010).

Similar to Scratch online environment is another tool, Crumble that combines block programming software with hardware and allows students to make electronic assemblies in a simple way but for beginner coders, Scratch is recommended before they can start using Crumble, followed by Arduino. As Scratch is an ideal tool for children and adults to learn with no prior programming or robotic experience (Plaza, Sancristobal, et al., 2018).

2.3.1.1. Robotic kits with Scratch

Research has found out that many hardware components can be integrated with scratch which allow easy programming as well as provide the opportunity to have a physical hands-on learning experience.

Lego Robots can also be programmed in the Scratch environment. “Lego WeDo” Construction Kit is a simple robotics tool designed for ages 7–11. It allows users to design their own interactive machines, and then program them using drag-and-drop coding blocks. The Lego WeDo Construction Kit can be used with the online editor of Scratch 2.0 by adding an extension. The robotics kit connects over Bluetooth to Scratch platform. Combined use of Scratch and WeDo in robotic projects falls under constructionism learning. These two platforms greatly facilitate introduction of programming and robotics in primary school (Olabe et al., 2011). To connect “Lego Mindstorms NXT” to Scratch, Enchanting is a modification that is used. “Lego Mindstorms Education EV3” can also be connected to scratch by enabling

an extension inside the Scratch environment expanding possibilities and allowing learners to build robotic puppets and tell stories, make musical instruments and game controllers etc.

“Finch” is a small simple robot designed by Carnegie Mellon’s CREATE lab. It is connected by USB and requires Bird brain robot server. It has support for a range of programming languages and environments and can be integrated with Scratch.

Similarly, “Hummingbird” is a Robotics kit that comprises of lights, sensors and motors which allow students to build a robot out of any material and needs Birdbrain server to run. Hummingbird epitomizes a low-floor, high-ceiling approach; it is suitable for beginners and allows learning advanced engineering and programming as well.

The “micro:bit” is a tiny circuit board designed to help kids learn to code and create. It can be programmed in Scratch by enabling an extension inside the Scratch platform.

Furthermore, “S4A” is a Scratch modification that allows simple programming of the Arduino hardware platform. It provides new blocks for managing sensors and actuators connected to Arduino. “Makeblock” is a similar programming environment and allows Scratch visual programming language with Arduino.

The “GoPiGo3” is a Raspberry Pi Robot Car kit that is easy to build and program with Scratch, Python, Blockly, and other programming languages.

“ScratchJr” is a visual programming language designed to introduce programming skills to children ages 5–8. By creating projects in ScratchJr, young children can learn to think creatively and reason systematically, despite not being able to read. Some commercially developed educational robots that can be integrated with Scratch and Scratch Jr are mentioned below (Mickel, 2015):

- Dash and Dot are robots produced by the California based start-up Wonder Workshop.

  The robots, intended for ages five and up, are fully assembled and available for

purchase as a set for $230. ScratchJr extension connects to Dash and Dot using their proprietary API via Bluetooth.

- Sphero and Ollie, created by Orbotix, are robots that drive around, change colour, and do various tricks, programmed in ScratchJr to drive and change colour.
- Light Play (and AdaFruit BlueFruit LE) project explores kids' experimentation and tinkering with light, colour, and shadows. ScratchJr extension to enable programmability of the direction and speed of the turntable, as well as the colour and intensity of the lights.
- KIBO, a programmable robot for children 4-7 years old ($229), is produced by KinderLab Robotics and Marina Bers (a collaborator on ScratchJr). The current version of KIBO is programmed by scanning wooden blocks (with barcodes).

Table 2.2: Competitors of Scratch

Platform	Age	Coding		Build Games	Gamification	Hardware integration	Free
		Block	Textual				
Snap	12+	Yes		Yes		Yes	Yes
Blockly	8+	Yes					Yes
Stencyl	12+	Yes		Yes			Yes
App inventor	10+	Yes		Apps		Yes	Yes
Game Salad	13			Yes			Trial
Tynker	5+	Yes	Yes		Yes		Trial
Code.org	K-12	Yes	Yes	Yes	Yes		Yes
Code monkey	K-8	Yes	Yes		Yes		Trial
Code Kingdoms	8+	Yes	Yes	Yes			Trial
Code Combat	Gr 5+		Yes		Yes		No

Alice	Gr 6+	Yes	Yes	Yes			Yes
Kodable	4-10	Yes	Yes		Yes		Trial

2.3.2. Minecraft

Minecraft is an open-ended game where players gather resources and build structures by destroying and stacking 3D blocks in a virtual world. It is among the most popular video games of all time with over a 100 million registered users (Makuch, 2014).

Minecraft has been adopted by educators worldwide for educational purposes (Schifter et al., 2013). Its rise and popularity can be attributed to the reason that interactions in Minecraft involve a broad range of educationally relevant content compatible with classical and modern theories of learning (Lane et al., 2017b).

Additionally, Minecraft for Education Edition (MinecraftEdu) is successful as it offers engaging educational content with variety of features designed to help students learn the basics of programming and apply coding on STEM subjects. It also has a flexible curriculum contributing to the development of computational thinking skills. It is possible to discover conditions, functions, coordinates and coding concepts with Minecraft for students of different ages (Minaudo, 2020).

Taking programming to a further gamified approach, "Hour of Code" Minecraft supports learning with engaging game-like graphics, a model world revolving around a storyline, tutorial instructions and a block-based programming language like Scratch. (Ghasemaghaei et al., 2017).

Minecraft is being used by educators in STEM subjects. In Science it is used to show how atoms become stable and unstable and to illustrate the features of cells. In Mathematics, it helps students visualise mathematic equations. For educators in language, history and arts, Minecraft can be used to help students experience historic locations, artistic periods and

architectural traditions (Brand & Kinash, 2013). Building a functioning clock from scratch in Minecraft requires an understanding of circuitry, the ability to make the appropriate calculations, and the ability to craft and design a model. Therefore, building a clock would relate to electrical engineering, mathematics, and mechanical engineering (Lane et al., 2017a).

Students working with Minecraft are unafraid to try a different configuration, to make a new tool, or to discover the attributes of a stone. Their only limitations may be what questions to ask and which problems to solve, and that is where the teacher contributes meaningful scenarios and pertinent questions reflective of the curriculum (Bos et al., 2014).

Minecraft's state and action space allow users to create complex systems, including logic gates and functional scientific graphing calculators. It can serve as a platform to model a wide range of robotics tasks such as cooking assistance, assembling items in a factory, object retrieval and complex terrain traversal (Aluru et al.,2015).

2.3.2.1. Robotics with Minecraft

Minecraft also provides opportunities to players to learn and experiment with robotics. "Code Builder" is a tool that shows up in the Minecraft game as a robot. Users can interact with the game through the robot agent via learn-to-code platforms such as Tynker, Scratch and MakeCode using which players program actions that the robot performs in the game, just like a physical robot would execute instructions. This allows players to experience in-game virtual robotics. Another platform, "ComputerCraftEdu" brings programmable turtle robots to Minecraft. Players start with a tile-based interface to learn the fundamentals of programming in a fun, accessible environment. They get engaged and motivated to find ways to use turtles to automate and extend their usual Minecraft activities using this software. ComputerCraftEdu comes included in MinecraftEdu but can also be downloaded separately for both MinecraftEdu and regular Minecraft.

Extending Minecraft to physical robotics, some projects have been made using Arduino, Raspberry Pi and Lego NXT in Minecraft by keen learners including Minecraft controlled Raspberry Pi Robotic arm (*Robots and Physical Computing: Minecraft Controlled Raspberry Pi Robot Arm*, n.d.). A tool "MCreator Link" enables users to connect hardware devices such as Arduino and Raspberry Pi with Minecraft game via MCreator procedures, commands and general API for Minecraft mod developers.

2.4. Learning through Play

"Informed Learning is when children learn through their own exploration and activity, as they follow their personal interests and grasp concepts naturally. Also referred to as playful learning," (*Playful Learning - Delaware Children's Museum*, n.d.). "Playful learning, also referred to as learning through play, is an approach that uses children's play to support discovery learning and problem-solving" (*Playful Learning | Early Learning Toolkit*, n.d.).

Learning through play is a widely explored approach to learning and teaching and has been used for children's learning. Research into playful learning approaches relating to adults is more limited. Defining play or playful behaviour is difficult to do as it contains many context dependent qualities. However, Play can be defined as an experience; it has intrinsic rather than extrinsic motives; the process is more important than the outcome and it involves some level of active engagement (Henricks, 1999).

Learning through play is a critical element for young children to develop key skills in language, emotion, creativity and social interaction, it pulls together the logical and creative areas of the brain that result in intrinsic motivation to perform a task.

In the world of new technologies, the forms of education are changing, as are the sites on which education occurs. Some scholars argue that the school of the future should be based predominantly on innovation and interactive creativity with new technology and new ways of acting (e.g. Natriello, 2007; Sawyer, 2006; Tuomi, 2007). This aim has been widely recognised

globally in educational contexts, and it has been concluded that formal teaching approaches may not match the learning methods used by children and young people (Sawyer, 2006). It also is argued that many students learn to solve specific types of problems but are unable to respond to unexpected situations, which inevitably arise in today's fast-changing world (Resnick, 2007). As Resnick (2007) and Sawyer (2006) assert, most schools are not focusing on helping pupils develop as creative thinkers and are not teaching them to create knowledge. Instead, in formal schooling, children are typically taught that knowledge is static and complete; they become experts at consuming knowledge rather than producing and creating it. Thus, innovative ways of using information and readiness to deal with the unexpected demands importance (Kangas, 2010).

Play has its value as a mean in children's learning. As humans are born curious, it is but a natural way to learn because it uses all senses to solve problems and understand the environment. Play prepares children for academic learning as they begin their school years and each step along the way (Rapeepisarn et al., 2006).

To give theoretical construction to the term playful learning, we will define it in the context of 'magic circle'. The term 'magic circle' was originally coined by Huizinga (1955) as an example of a space in which play happens. It is the space in which the normal rules and reality of the world are suspended and replaced by the artificial reality of a game world. Within this definition of the magic circle, there are three key pedagogical characteristics for using playful approaches to learning in higher education: the positive construction of failure; support for learners to immerse themselves in the spirit of play; and the development of intrinsic motivation to engage with learning activities (Whitton, 2018). This helps build resilience to failure and fosters the ability for students to take measured risks, making them innovators focusing on learning challenges rather than the measurable outcomes (Dweck, 2010). This ability to enter a parallel fantasy world sets the imagination free and leads to greater creativity and innovation

(Bateson & Nettle, 2014). Activity within the magic circle is by choice and intrinsically motivated. Participation is motivated by the internal benefits of play, rather than for any external rewards. Intrinsically motivated engagement allows for personal exploration, experimentation and discovery, leading to personally meaningful learning (Whitton, 2018).

Techniques that encapsulate elements of play involve role play or storytelling, aspects such as making, building or tinkering that involve playful experimentation and learning through errors and making mistakes. They also include playful ways of framing challenges to support motivation, such as the use of problems or quests. These types of challenge create motivation for people to engage and stimulate curiosity and feelings of satisfaction on completion.

Playful approaches to learning can be an effective mode of teaching and learning requiring activity and sensation, but experience alone is not always enough to achieve learning. There must be some critical reflection to turn the experience into learning (Rice, 2009). The inclusion of play helps to generate excitement, enjoyment and interest as part of the process of learning. It can be understood as part of the VARK learning approaches, which help with motivation, engagement, and allow different learners to approach a subject from different perspectives. To conclude, playful learning requires a shift from students being passive consumers of knowledge towards active creators of knowledge. Primarily for this research, we will define playful learning as an activity by the learner, aimed at the construction of a mental model, that is designed to include one or more elements of games for the purpose of enhancing the learning process. Depending on learning goals, learners, settings, and other factors, designers conceptualize and implement playful learning environments that are either games, or that incorporate game-like elements (Plass et al., 2014). We will henceforth use the term playful learning to describe learning that incorporates game elements and explore further on that subject below.

2.4.1. Game Design for Learning

Some of the fundamental elements of game design include game mechanics, visual aesthetic design, narrative design, incentive system, musical score, content and skills (Plass et al., 2014). The motivational function of games is their most frequently cited characteristic. Motivation and engagement of young pupils are sought through the gamification of the learning process (Kintsakis & Rangoussi, 2017).

During the research intervention by Kintsakis & Rangoussi (2017) pupils were found motivated and engaged, thanks to the graphics, the look and feel of the environment and the gaming elements. Hence, it is found that multimedia elements (animation, graphics, video, frames) greatly facilitate and enhance the reception of subject matter.

Using games effectively during instruction encourages students to actively participate in their own learning (Leonard et al., 2016). A variety of gaming strategies have been employed in education such as game design and programming (Webb, P. I. & Pearson, 2012), mobile games (Koutromanos & Avraamidou, 2014), online games (Mysirlaki & Paraskeva, 2010) and game authoring tools (Robertson & Howells, 2008).

Studies related to gaming have demonstrated development of a more positive attitude and motivation toward mathematics (Ke, 2008). Ke (2008) conducted a study that explored the effect of using a series of web-based games called *ASTRA EAGLE* on cognitive mathematics accomplishment, metacognitive awareness, and favourable attitudes toward mathematics among elementary students in Pennsylvania. Results revealed that children developed positive attitudes toward learning mathematics through gaming. Digital game playing has also been used successfully to teach mathematics problem-solving (Chang et al., 2012) and can be used as a social practice to support the development of ''strategic thinking, planning, communication, application of numbers, negotiating skills, group decision making, and data-handling'' (Li & Ma, 2010). Incorporating computer games in the mathematics classroom has

been shown to lead to favourable attitudes toward learning mathematics and to increases in mathematics achievement and student success.

Serious Educational Games (SEGs) can bring about a life-like experiences and assist in the creation of problem-based learning that cannot be replicated in the traditional science classroom or even on field trips (Lamb et al., 2015). Furthermore, SEGs have shown positive gain-scores after science students played teacher created games. According to a study, science students who participated in a game based activity displayed more levels of engagement than students who participated in non-game based activity (Annetta, 2010).

The research literature tells us that twenty-first century skills include media-based intangibles often found in video games. The ideas of play, performance, multitasking, distributive cognition, networking and negotiation are not only common in games but have become some of the common characteristics found in today's school age students (Annetta et al., 2013).

Ricci et al. (2014) proposed that instruction that incorporated game features enhanced student motivation, which led to greater attention to training content and greater retention. Thornton & Cleveland (1990) noted that the essential aspect of a game is interactivity. Gredler (1996) stated that the essential elements are a complex task, the learner's role, multiple paths to the goal, and learner control. Malone (1981) argued that there are four characteristics of games that make them engaging educational tools: challenge, fantasy, complexity, and control.

Modern Game-Based Learning (GBL) approaches are commonly build on applications that have defined learning outcomes and are designed to promote active participation and interaction, balancing the learning objective with the gameplay, in order to enhance the ability of the learner to retain and apply the knowledge gained to the real world while being completely involved and thus more receptive. SEGs often exploit narratives, storylines, visual elements and other features common to entertainment games, such as scoring and social networking in

order to motivate and engage players in a learning activity. Educational games have learning goals and structure, but in addition are adaptive and interactive and most importantly they provide enjoyment, pleasure, motivation, gratification and emotion, in order to achieve learner engagement and involvement. Games create simulated environments that facilitate immersion, allowing learners to explore alternative approaches to situations virtually, in order to directly experience practical and emotional consequences of their actions. Through these approaches, GBL allows learners to directly though virtually, experience the real-world by developing their awareness of real situations (Protopsaltis et al., 2010).

2.5. Identifying Research Gaps

As digital creation tools become more prevalent, early childhood education remains an area in which few educational technologies focus on digital creation or high-level thinking (Flannery et al., 2013). It is not the hardware or the software, but the combination between the use of the new interactive technologies and the pedagogical approach that has the possibility to facilitate significantly young children’s learning achievement (Papadakis et al., 2016).

Researchers have explored robotics as a platform for teaching mathematics, physics, programming and engineering design and problem solving. Yet, only some of these studies defined exactly the specific knowledge of mathematics, science and technology the student should learn in a robotics program or evaluated how robotics activities contributed to students’ learning in these subjects (Highfield, 2010).

Physical contact in the classroom is generally thought to be superior in developing and maintaining motivation and engagement of the pupils, as well as in achieving the desired learning outcomes. The suitability of e-learning for younger ages and especially for Primary Education, therefore, is still an open issue, GBL, or even the mere gamification of the learning process, is a valid method to achieve motivation and engagement across all grades of education, even more so for younger pupils. How this method can be utilized for early ages specially in

STEM still needs research and motivation through gamification is usually extrinsic in nature. How intrinsic motivation can be achieved through gamification is still a question.

ER is still frequently associated with teamwork and problem-solving development, extracurricular activities, and Lego robots (Khine, 2017). Robotics projects are more commonly associated with technology and engineering. There is limited focus towards science and maths. ER activities are more focused towards information technology and not STEM (Kucuk & Sisman, 2020).

In school reality, teachers are the key factor to the application of Robotics Education. More investigation is also required on how teachers could use better these digital tools. (Dorouka et al., 2020). There is significant scope to enhance the trust levels of teachers and students in the robotics for STEM education (Hu & Garimella, 2015).

The research of the learning effect of games is still in the beginning, but some studies already show the potential of games such as students staying more motivated when learning with a game (Garris et al., 2002).

The extensive literature review suggests that significant research is available in the field of STEM, including integration of robotics and online learning platforms such as Scratch and Minecraft in classrooms to teach STEM. However, there is scarcity of research available on incorporating playful learning approach to teach STEM concepts to young learners in an online learning environment; using robotics or games that keep the learner intrinsically motivated and result in effective learning outcomes.

3. Research Design

3.1. Defining the Research Problem

The literature review suggests that research to teach STEM concepts online using playful learning approach is insufficient. Furthermore, imparting knowledge online in domains that require physical learning aids such as STEM has been very difficult in COVID. Thus, to create an engaging e-learning environment that results in effective learning outcomes and keeps the learners intrinsically motivated, further research is required.

3.2. Research Plan

Playful learning in higher education currently lacks a coherent definition, evidenced pedagogic rationale or framework of implementation approaches. Playful learning in higher education is an emerging form of practice that includes many types of playful approaches to teaching, learning, research and academic practice. These approaches facilitate positive attitudes towards failure, embody a spirit of play and experimentation, and enhance intrinsic motivation. Whitton (2018) categorised these playful approaches into three distinct groups: playful tools, playful techniques, and playful tactics. Outlined below in table are playful learning tools, techniques and tactics (Whitton, 2018).

Table 3.1: Playful Learning

Playful Learning	Description	Examples
Tools	Objects, artefacts and technologies that signify a playful environment	Games Toys Simulations Puzzles Virtual environments
Techniques	Pedagogies and learning approaches that facilitate play	Role play Making Performance Problems Quests

Tactics	Mechanics and attributes that engender playfulness	Surprise Humour Chance Competition Storytelling Mystery Badges

For our research, we aim to incorporate the relevant tools, techniques, and tactics through an integrated design framework of game-based learning to attain playful learning thus fostering engagement of learner.

3.2.1. Integrated Design Framework

The framework we have chosen to implement for this study is proposed by Jan L. Plass, Bruce D. Homer and Charles K. Kinzer. It describes what kinds of engagement playful learning environments allow and defines the game design elements that create such engagement (Plass et al., 2014).

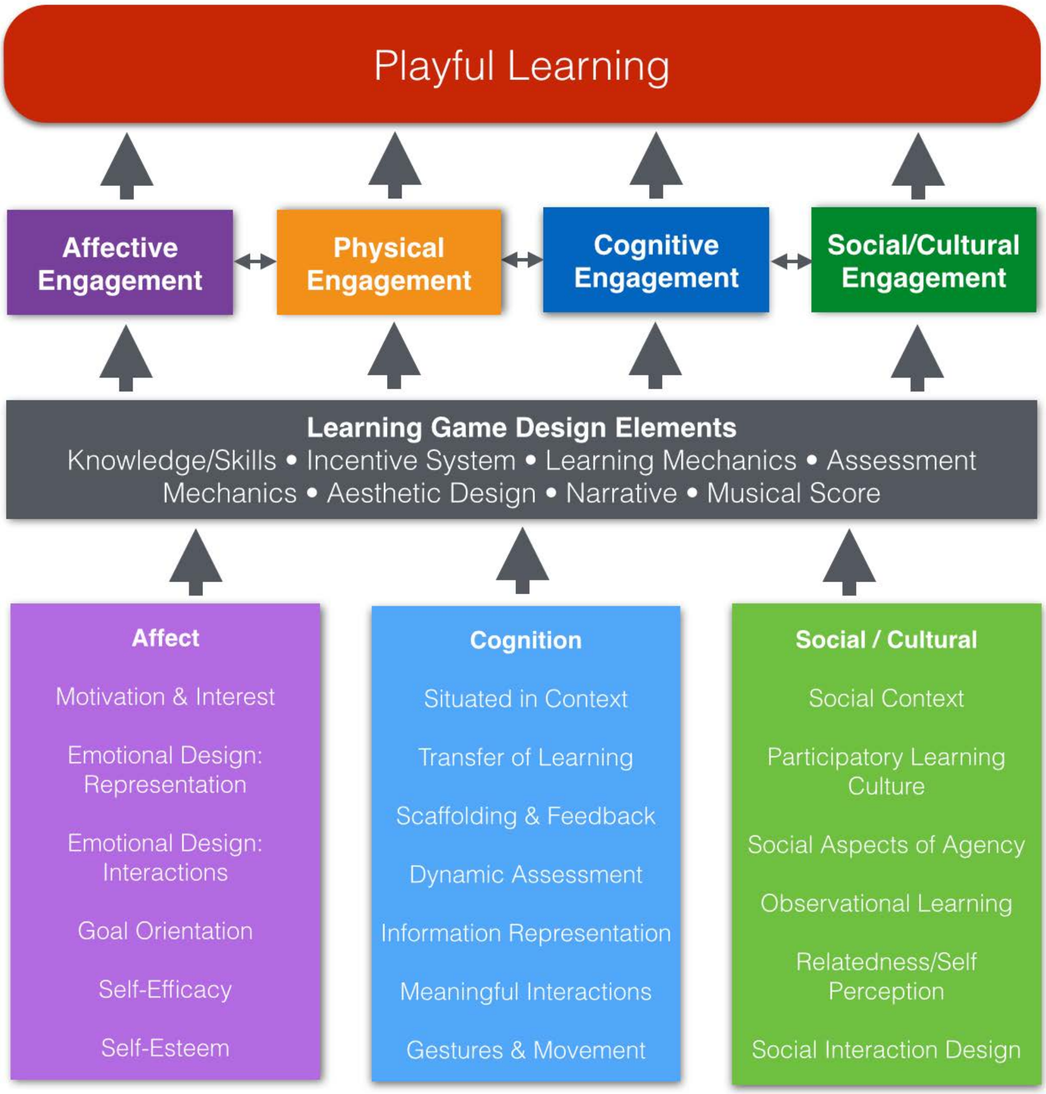


Figure 3.1: Integrated Design Framework of Playful Learning

4. Methodology

4.1. Overview

The basic idea of this study was to implement playful learning techniques to teach STEM concepts and check if it impacted engagement levels for students in an online educational environment. The topic chosen was ‘speed, distance and time’. A Quasi-experimental study was conducted. Post-test only control and experimental group design was employed.

4.2. Group Allocation

Since the purpose of this research was to compare if using playful approach to learning impacted the engagement levels of students for teaching STEM concepts in an online setting, the quasi experiment was conducted on students ranging between ages 11 to 14.

Students of Grade 6 and 7 from Army Public Schools in Rawalpindi and Nowshera were chosen for the control and experimental groups.

To set up an environment for a fair comparison, students of Grade 6 and 7 were chosen from Army Public School Fort Road, Rawalpindi and Army Public School Iqbal, Nowshera. These students were then divided into control and experimental groups. Choosing different locations allowed to cater for diversity of learners. To ensure uniformity, all the sections were taught the same topic by the researcher, keeping pedagogy different for control and experimental groups. Learning objectives pertaining to the topic were kept same for all sections. The topic ‘speed, distance and time’ was taught using an applied interdisciplinary approach using examples from daily life to ensure underlying STEM concepts are conveyed to both the groups.

4.3. Group Size

The control and experimental groups comprised of 50 participants each. Table summarized the demographics of the participants.

Table 4.1: Participant's demographics

Categories	Schools		Grade		Group	
	APS Fort Road (Rawalpindi)	APS Iqbal (Nowshera)	Grade 6	Grade 7	Control	Experimental
No. of Participants	61	39	54	46	50	50

4.4. Procedure

4.4.1. Research Questions

This study was an attempt to compare playful pedagogy with traditional teaching methods in online learning during the lockdown period in COVID. The subject under study was STEM education using robotics. This research was designed to investigate whether playful learning techniques supported with technology could substantially increase engagement of learners. Thus, to aid the research, the following questions were formulated.

Research Question 1: Incorporating playful learning in online STEM education through game design elements impacts learner's engagement?

Research Question 2: Are learning outcomes achieved through online STEM?

4.4.2. Variable Selection

As the integrated design framework mentions different types of learner engagements. To answer our first research question, we selected engagement as the variable to be tested, further subdivided into affective, physical (behaviour) and cognitive categories.

For our second research question, student score attained in post-test was our selected variable.

4.4.3. Hypothesis Formulation

To compare engagement levels across control and experimental groups, we would use exploratory data analysis which is an approach to analysing data sets to summarize their main

characteristics, often with visual methods. Since choosing a statistical method is not necessary to evaluate findings in this case; we have not specified a hypothesis to be tested, rather we aim to conduct our investigation through graphical representation of data and compare results.

The following hypotheses are formulated to assess whether learning outcomes are achieved in online STEM education.

H_0: Marks obtained in post-test are equally high for playful and traditional methodology.

H_a: Marks obtained in post-test are not equally high for both playful and traditional methodology.

4.4.4. Experimental Study

Experimental research was conducted for this study which falls under the quantitative paradigm. The type chosen was Quasi-experimental study. Quasi-experimental or field research is conducted in a natural setting as opposed to a laboratory set up. The variables are isolated, controlled and manipulated to suit the needs of the research question (Cohen et al., 2018). However, the researcher does not exercise complete control over the research setting (experimental conditions or extraneous variables) as in an experimental design. Quasi-experimental designs are frequently used in social science and healthcare research (Harris et al., 2006) when randomisation or the use of control groups is unfeasible.

For this research, non-equivalent control group post-test only design was employed. A non-equivalent group design is a quasi-experiment used to assess the relative effects of treatments that have been assigned to groups of participants nonrandomly. This design can be used in situations where randomisation is unfeasible because of ethical or practical considerations or it is too late or impossible to collect pre-test data. In studies that use the design, the intervention is implemented for the experimental group, which is then compared to

the non-equivalent control group and outcome measurements are taken from both groups (Polit, D.F.,& Beck, 2015).

4.4.4.1. Control and Experimental Groups

The purpose of a control group is to determine what outcome will occur in case the intervention, had not taken place. The experimental group is part of the population sample undergoing research intervention. For this study, control group and experimental group differ in their applied pedagogy. The control group is taught using the traditional online teaching method selected for imparting education during COVID, whereas, the experimental group is taught online using playful pedagogy and concept of robotics to make learning engaging for students. Both the groups are taught the same topic of “speed, distance and time” based upon STEM by the same instructor to keep the study as fair as possible.

4.4.4.2. Post-test

To collect data from the control and experimental groups, post-tests are conducted. To assess engagement levels during the study, an engagement survey was taken from the students whereas to assess learning, students from both the groups were asked to fill an MCQ based test. The post-test results of both control and experimental groups show the changes (if any) from the intervention.

4.4.5. Content Design

The topic chosen for the study was “Speed, Distance, and Time” in STEM education. Lesson was designed for control and experimental groups along the lines mentioned in the table below.

Table 4.2: Content Design

Groups	**Experimental**	**Control**

Content Delivery	Playful approach using - Elements of game design - Robotics website	Traditional content delivery by - Usual expression (Slides) - Worksheet
STEM in the lesson	• Science: speed, time, distance • Engineering: problem solving, coding • Technology: robotics, online learning tool • Math: degrees, units, % • Robotics • Coding	• Science: Speed, distance, time (concepts of physics) • Math: variable relationship (equation) • Technology: online learning platform • Engineering: problem solving • *MISSING:* - *Robotics* - *Coding*
Learning Objectives	• Recall concepts of speed, distance, and time • Calculate distance, speed and time • Understand variable relationships • Apply STEM concepts in real life • *Understand programming instructions* • *Analyse angles and degrees* • *Plan and predict program execution* • *Create programs by using different sets of instructions*	• Recall concepts of speed, distance, and time • Calculate distance, speed, and time • Understand variable relationships • Apply STEM concepts in real life

4.4.5.1. Lesson Plan

The lesson plan for control and experimental groups is outlined in the tables below.

Table 4.3: Lesson Plan Experimental Group

Timings	Description
00:00 – 00:05	Greetings Website Log in (https://vr.vex.com/)
00:05 – 00:10	- Narrative Building • Code the Robot to reach the destination

	- Competition (incentive) - Concepts • Coding Blocks
00:10 – 00:15	Activity 1: - Code Robot to reach on usual speed - Analyze speed time distance relationship
00:15 – 00:25	Activity 2: - Code Robot to reach by changing its velocity - Analyze speed time distance relationship
00:25 – 00:30	Reflection and Wrap up

Table 4.4: Lesson Plan Control Group

Timings	**Description**
00:00 – 00:05	Greetings + Welcome Note
00:05 – 00:15	• Objective • Brainstorming ➢ Speed ➢ Distance ➢ Time • Variable relationship
00:15 – 00:25	Word Problems Questions / Answers
00:25 – 00:30	Homework and Wrap up

To assess the content knowledge, following modes of assessment were included in content design.

Assessment for learning (AFL)

- Questions during lesson / activity to gauge learning

Assessment of Learning (AOL)

- Post-test MCQ's

4.4.6. Content Delivery

The research intervention was conducted online. Communication between teacher and students for both the groups was facilitated by Microsoft Teams as all the students already had their school login ID's and were taking their usual online classes during COVID lock-down on Microsoft Teams.

Topic "Speed, Distance, and Time" was delivered to both the groups such that STEM concepts are conveyed through the lesson and students understand real life applications of the topic being taught. Students were briefed learning objectives at the beginning of the lesson as follows.

At the end of the lesson, students would be expected to:

- Understand the correlation between speed, distance, and time
- Analyse variable relationships
- Derive further equations
- Apply equations to solve problems

4.4.6.1. Control Group

The lecture was delivered to the control group through slides by using PowerPoint presentation on MS Teams which was the usual method of content delivery.

Summary of the lesson is as follows:

- Brainstorming: Which travels faster? Race car or fastest human being?
- What is Speed and how do we measure it?
- Why does a speedometer measure speed in km/h?
- What is Distance?
- What is the relationship of Speed and Distance with time?

- How do we calculate Speed, distance, and time?
- Equations
- Word Problems and real-life examples
- Question/ Answers

4.4.6.2. Experimental Group

Content was delivered to the experimental group through inquiry-based instruction where students were immersed in discovery to achieve learning objectives of the lesson. Students were told that they would be playing to learn about “Speed, Distance, and Time”.

As the integrated design framework incorporates elements of game design to achieve playful learning, online learning platform *https://vr.vex.com/* was used to engage students in play and robotics. Game design elements were embedded in the lesson as outlined in the table below.

Table 4.5: Experimental Group Content Delivery

Elements	Description	In Lesson
Game Mechanics	the essential game play	online robotics platform https://vr.vex.com/
Visual Aesthetic Design	visual elements such as the overall look and feel of the game and of the game characters	online robotics platform https://vr.vex.com/
Narrative Design	storyline that is advanced via features such as cutscenes, in-game actions, dialogues and voice-overs	Narrative was built by the facilitator. Students were given the mission to program the robot to crash the castle in the online learning platform.
Incentive System	scores (points), stars, badges, trophies, power-ups, and many other rewards	Student who will complete the missions in minimum time will win
Content and Skills	the subject matter content and skills that the game is designed to teach	By performing the activity, learner will discover the relation • Speed α 1/ Time • Speed α Distance

		Thus establishing, • Speed = Distance / Time • Distance = Speed x Time • Time = Distance / Speed

Summary of the lesson is as follows:

- Introduction to robotics through daily life examples such as smartphones, washing machines, microwaves, computers etc.
- Programming robots means giving them set of instructions step by step for execution.
- Learning objectives that students are expected to discover in lesson
- Website log in and interface introduction
- Narrative building
- Continuous feedback and tasks to program robot
- Review of speed, distance, and time concepts and variable relationships that students learnt while playing the game
- Understand equations to calculate speed, distance, and time
- Questions/ Answers

4.4.7. Conducting Post-test

Two post-tests were conducted from control and experimental groups to collect data and answer the research questions. The post-tests were created using Google Forms and links were shared with the students at the end of the lesson.

To assess engagement levels, students were asked to fill out an engagement survey after the lesson. The survey was adapted from the engagement survey proposed by Chung et al., (2016) used to measure an individual's behavioural, cognitive, and affective engagement. The Engagement survey by Chung et al. was written for use with 10 to 14-year-old respondents immediately after a science activity, whether in a class or in an informal learning context. It is available at *http://activationlab.org/.* According to Chung et al., (2016) "Our analysis of the

internal structure of the instrument indicates that valid inferences can be made regarding the overall engagement (i.e., a combination of affective, behavioural, and cognitive engagement) during an activity using responses across all items. Equally valid inferences can be made for two sub-factors of the scale, specifically an affective score or a behavioural/cognitive score. Responses to the cognitive and behavioural co-occur so tightly that separating those scores is not typically meaningful. Due to the self-report nature, the survey is not intended for high-stakes decisions about students (e.g., pass/fail determination, selection of program participants) or programs. Instead, the instrument is intended for formative feedback and/or for research purposes". Hence, the survey fit well for our intended research's comparative analysis between control and experimental group. It allows measuring different levels of engagement as outlined in the integrated design framework we are using in this research study.

The second post-test, an MCQ based questionnaire aimed to test students' knowledge. Students were required to solve the word problems by using equations to calculate speed, distance, and time and choose the correct option.

4.4.8. Choosing Methods of Analysis

To test a hypothesis, a statistical test needs to be conducted. The statistical test used should be determined by the data.

There are 4 levels of data measurement:

- Nominal: the data can only be categorized
- Ordinal: the data can be categorized and ranked
- Interval: the data can be categorized, ranked, and evenly spaced
- Ratio: the data can be categorized, ranked, evenly spaced, and has a natural zero

To prove our hypothesis, the data collected by post-test MCQ's i.e. student scores will be analysed. In this case, the data is categorized, ranked and is evenly spaced so it falls under the category of interval.

Methodology

Parametric or non-parametric tests are chosen depending upon whether the data is normally distributed or not.

The Independent Samples *t* Test is commonly used to test the following:

- Statistical differences between the means of two groups
- Statistical differences between the means of two interventions
- Statistical differences between the means of two change scores

<u>Paired vs unpaired t-test</u>

A paired t-test is designed to compare the means of the same group or item under two separate scenarios and an unpaired t-test compares the means of two independent or unrelated groups. For this research study, we had two unrelated groups, experimental and control and we wished to find out statistical differences between the two interventions.

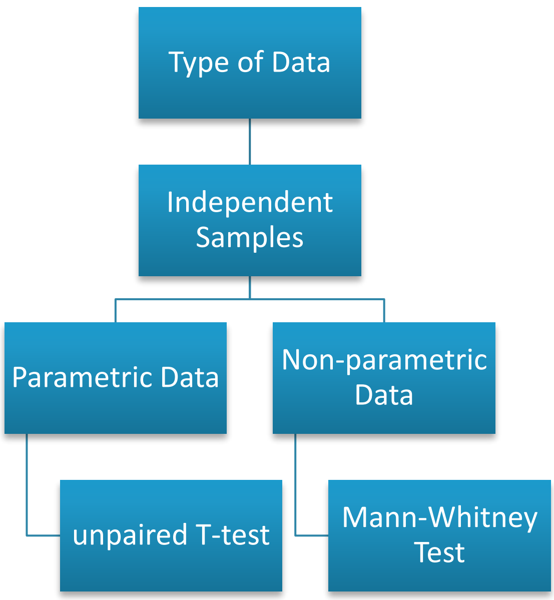


Figure 4.1: Statistical Tests

After running the normality test, the data was found to be non-normal. Therefore, non-parametric statistical test would be chosen.

The Mann-Whitney Test was chosen for this research as it is used to compare the means between two groups of non-parametric data.

4.5. Summary

A non-equivalent control group post-test only design was employed for this research. Students of Grade 6 and 7 from Army Public Schools were chosen for the control and experimental groups with 50 participants in each group (total sample size N=100). The topic 'speed, distance and time' was taught to both the groups by the same instructor using traditional and playful pedagogy for control and experimental groups respectively.

This research was designed to investigate whether playful learning techniques impacted learner's engagement and resulted in effective learning outcomes.

To collect data from the control and experimental groups, post-tests were conducted after the lesson was delivered. To assess learner engagement, exploratory data analysis was used to visually represent data and draw comparisons. Whereas, hypothesis was statistically tested to check if pedagogy had any impact on student scores. The Mann-Whitney Test was chosen in this case as data was non-parametric. The results and findings of the study are explained in detail in the next chapter.

5. Data Analysis

5.1. Overview

Data was collected through post-tests after the implementation of the design experiment from control and experimental groups. Google Forms were used to collect the data which was then exported to excel sheets and tabulated. Statistical tests and exploratory analysis were conducted on the data using SPSS. Sample size was a total of 100 participants with 50 participants in each control and experimental groups.

5.2. Data Collected

To answer our research questions, the data collected was divided in two parts and analysed.

5.2.1. Part One: Engagement Survey

To assess engagement levels, students were asked to fill out an engagement survey following the research intervention. The survey was adapted from the engagement survey proposed by Chung et al., (2016) used to measure an individual's behavioural, cognitive, and affective engagement. Data was collected from the participants through Google Forms. The aim of this engagement survey was to answer the research question, "Incorporating playful learning in online STEM education through game design elements impacts learner's engagement?"

To analyse the data collected from the survey, we used Exploratory data analysis (EDA) which is a technique used by data scientists often employing data visualization methods to analyse and investigate data sets and summarize their main characteristics.

Data was plotted visually to depict differences between engagement levels of control and experimental groups. Engagement levels were subdivided into Affective, Cognitive and Behaviour domains so to complement our integrated design framework deployed in the research study.

It was concluded that engagement levels of experimental group undergoing playful learning were higher as compared to the engagement levels of control group taught through traditional pedagogy. This pattern was observed similar across Affective, Cognitive and Behaviour domains. Refer to Figure 5.2 for visual representation of data.

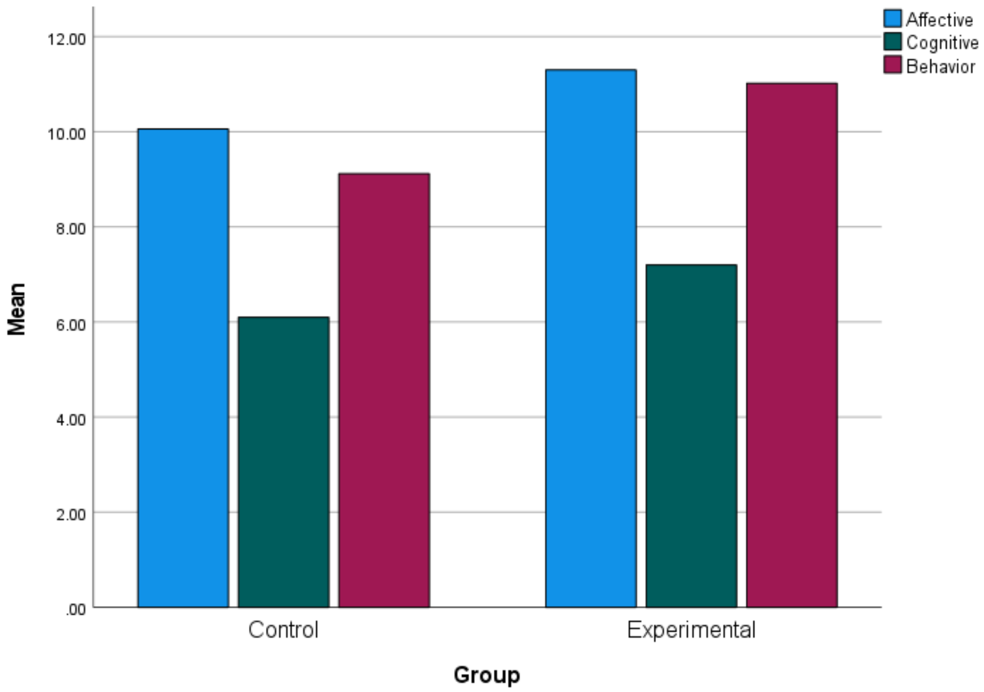


Figure 5.1: Data Analysis of Engagement Survey

Furthermore, graphs were plotted to investigate engagement patterns across Class, Schools and Ages. It was concluded that experimental group showed higher levels of all 3 engagement domains across all variables. Data is depicted in Figures below.

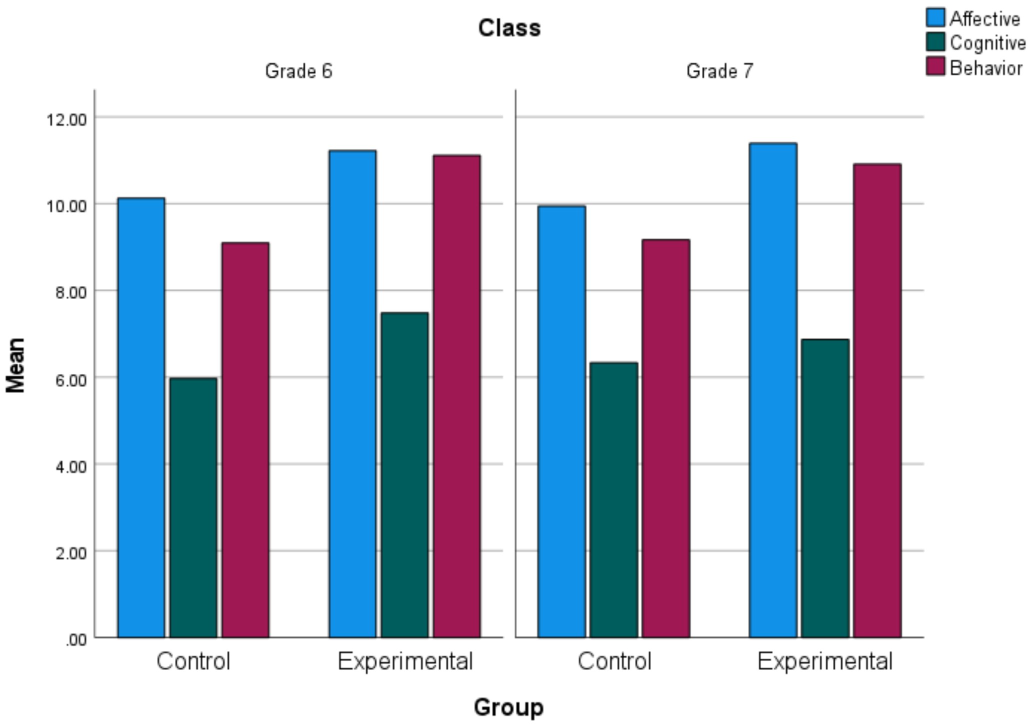


Figure 5.2: Engagement levels across Class

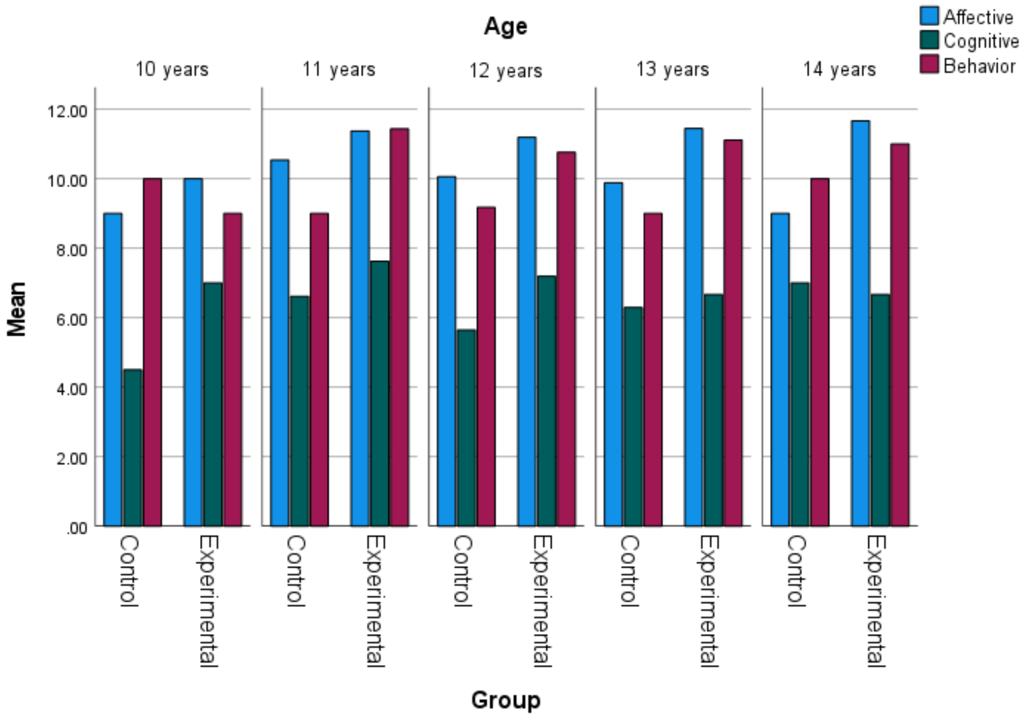


Figure 5.3: Engagement levels across Age

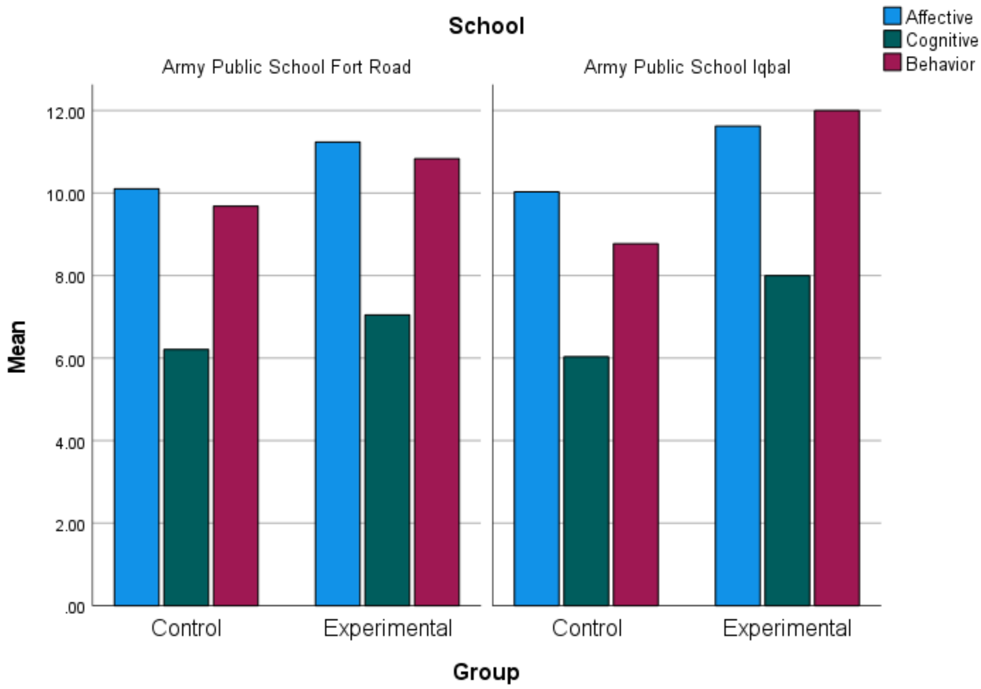


Figure 5.4: Engagement levels across Schools

5.2.2. Part Two: Post-test Score

To answer our research question "Are learning outcomes achieved through online STEM", the following hypotheses were formulated. Tests were run on student 'scores' obtained in post-test MCQ's.

H_0: Marks obtained in post-test are equally high for playful and traditional methodology.

H_a: Marks obtained in post-test are not equally high for both playful and traditional methodology.

5.2.2.1. Normality tests

Normality tests were run on control and experimental group data comprising of 50 data values each; to check whether the data requires parametric or non-parametric statistical test to be run. The Shapiro Wilk test was used to test for normality in SPSS.

The tables below present the results from two well-known tests of normality, namely the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test. The Shapiro-Wilk Test is more appropriate for small sample sizes (<= 50 samples) but can also handle sample sizes as large as 2000. If the Sig. value of the Shapiro-Wilk Test is greater than 0.05, the data is normal. If it is below 0.05, the data significantly deviates from a normal distribution.

Hence, we can conclude from the tables below that “Score” is not normally distributed for control and experimental groups.

Table 5.1: Normality Control Group

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Score	50	100.0%	0	0.0%	50	100.0%

Descriptive				
			Statistic	Std. Error
Score	Mean		4.36	.106
	95% Confidence Interval for Mean	Lower Bound	4.15	
		Upper Bound	4.57	
	5% Trimmed Mean		4.44	
	Median		4.00	
	Variance		.562	
	Std. Deviation		.749	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		1	
	Skewness		-1.316	.337
	Kurtosis		2.166	.662

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Course	Statistic	df	Sig.	Statistic	df	Sig.
Score	.283	50	.000	.732	50	.000

Table 5.2: Normality Experimental Group

Case Processing Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Score	50	100.0%	0	0.0%	50	100.0%

Descriptive				
			Statistic	Std. Error
Score	Mean		3.60	.185
	95% Confidence Interval for Mean	Lower Bound	3.23	
		Upper Bound	3.97	
	5% Trimmed Mean		3.66	
	Median		4.00	
	Variance		1.714	
	Std. Deviation		1.309	
	Minimum		1	
	Maximum		5	
	Range		4	
	Interquartile Range		3	
	Skewness		-.341	.337
	Kurtosis		-1.305	.662

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Score	.218	50	.000	.847	50	.000

Since the data was found to be non-normal, non-parametric statistical test was required for data analysis.

5.2.2.2. Mann-Whitney Statistical Test

The Mann-Whitney U test is a non-parametric test that can be used in place of an unpaired t-test. It is used to test the null hypothesis that two samples come from the same population (i.e. have the same median) or, alternatively, whether observations in one sample tend to be larger than observations in the other the null and two-sided research hypotheses for the nonparametric test are stated as follows:

- H0: The two populations are equal versus
- H1: The two populations are not equal

For data analysis of student score to assess learning outcomes, we chose Mann-Whitney non-parametric test. The test was run on the data (student scores attained in post-test MCQ's) across different variables. Details are as follows.

- **Score across categories of Group**

The test was run on variable score across control and experimental groups to verify the following hypotheses.

H_0: Marks obtained in post-test are equally high for control and experimental groups.

H_a: Marks obtained in post-test are not equally high for control and experimental groups.

The null hypothesis was rejected as result of statistical test. It was concluded that Marks obtained in post-test were not equally high for both control and experimental groups exhibiting traditional and playful pedagogy respectively. It was depicted that Control Group showed higher marks in score. Output of the test are listed in tables below.

Table 5.3: Mann-Whitney Test across Groups

Hypothesis Test Summary			
Null Hypothesis	**Test**	**Sig.[a,b]**	**Decision**
The distribution of Score is the same across categories of Group	Independent-Samples Mann-Whitney U Test	.005	Reject the null hypothesis

Independent-Samples Mann-Whitney U Test Summary	
Total N	100
Mann-Whitney U	870.000
Wilcoxon W	2145.000
Test Statistic	870.000
Standard Error	136.807
Standardized Test Statistic	-2.778
Asymptotic Sig.(2-sided test)	.005

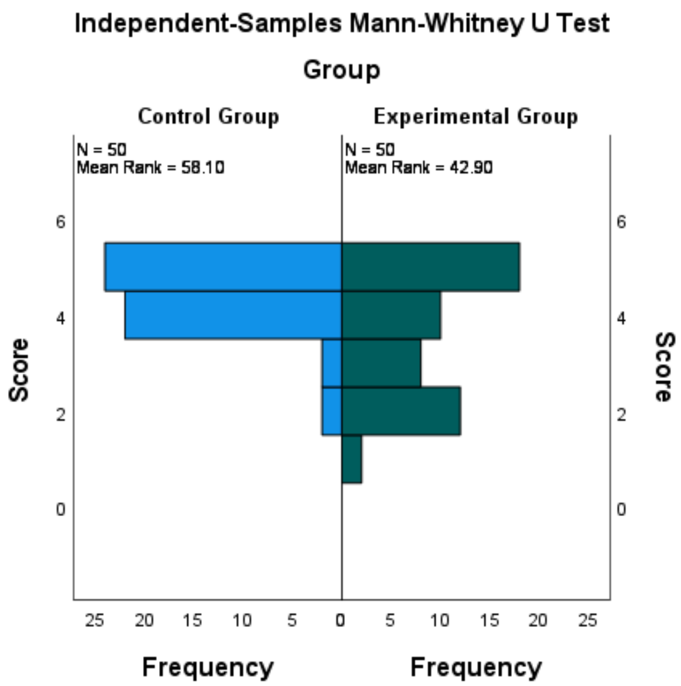
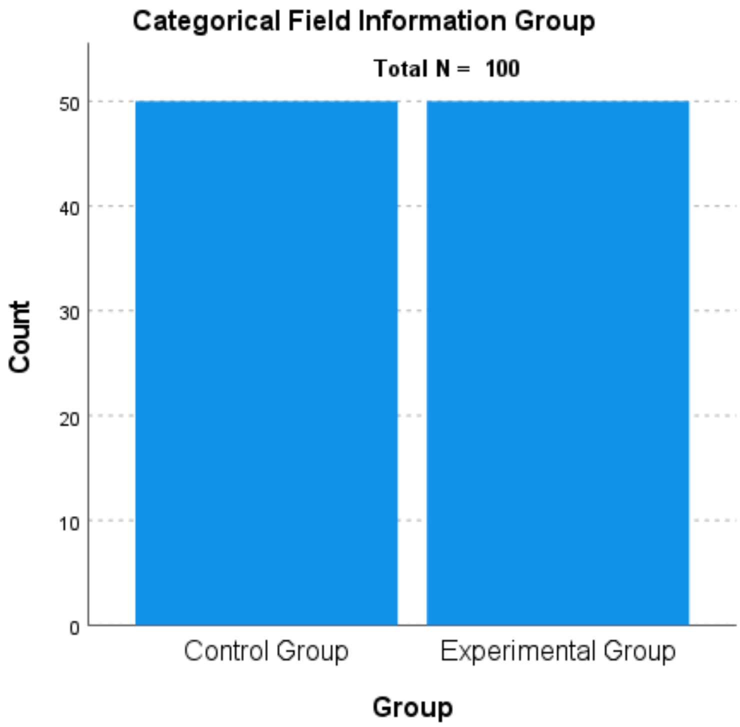
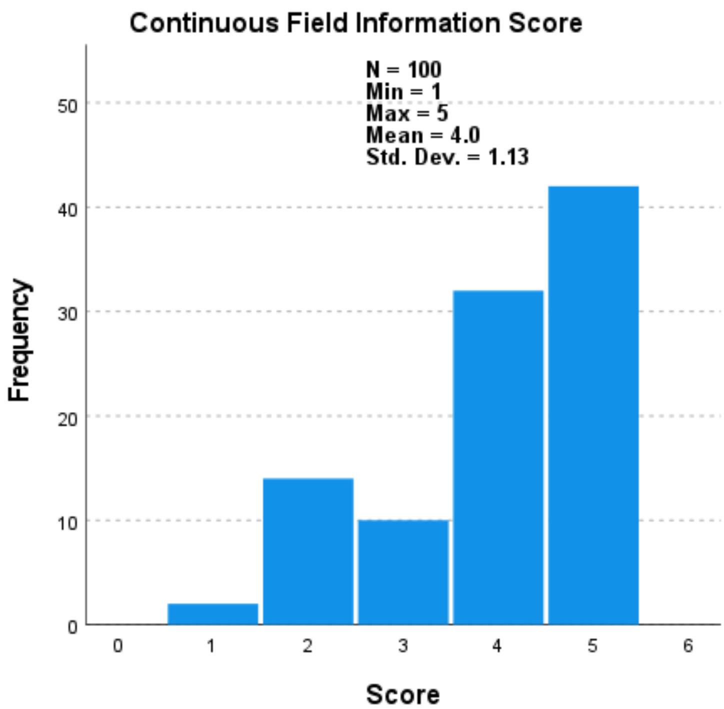


Figure 5.5: Mann-Whitney Test across Groups


Categorical Field Information Group
Total N = 100
50
40
30
20
10
0
Count
Control Group
Experimental Group
Group


Continuous Field Information Score
N = 100
Min = 1
Max = 5
Mean = 4.0
Std. Dev. = 1.13
50
40
30
20
10
0
Frequency
0
1
2
3
4
5
6
Score

- **Score across categories of School**

The test was run on variable score across Army Public School Iqbal (Nowshera) and Army Public School Fort Road (Rawalpindi) to verify the following hypotheses.

H_0: Marks obtained in post-test are equally high for Army Public School Rawalpindi and Army Public School Nowshera.

H_a: Marks obtained in post-test are not equally high for Army Public School Rawalpindi and Army Public School Nowshera.

The null hypothesis was retained as result of statistical test. It was concluded that Marks obtained in post-test were equally high for both schools that were part of the research. It was depicted that score was attained similarly for students irrespective of their schools. Participants of Rawalpindi were more as compared to Nowshera as APS Rawalpindi has more student strength. Output of the test are listed in tables below.

Table 5.4: Mann-Whitney Test across Schools

Hypothesis Test Summary			
Null Hypothesis	**Test**	**Sig.[a,b]**	**Decision**
The distribution of Score is the same across categories of School	Independent-Samples Mann-Whitney U Test	.637	Retain the null hypothesis

Independent-Samples Mann-Whitney U Test Summary	
Total N	100
Mann-Whitney U	1126.500
Wilcoxon W	1906.500
Test Statistic	1126.500
Standard Error	133.455
Standardized Test Statistic	-.472
Asymptotic Sig.(2-sided test)	.637

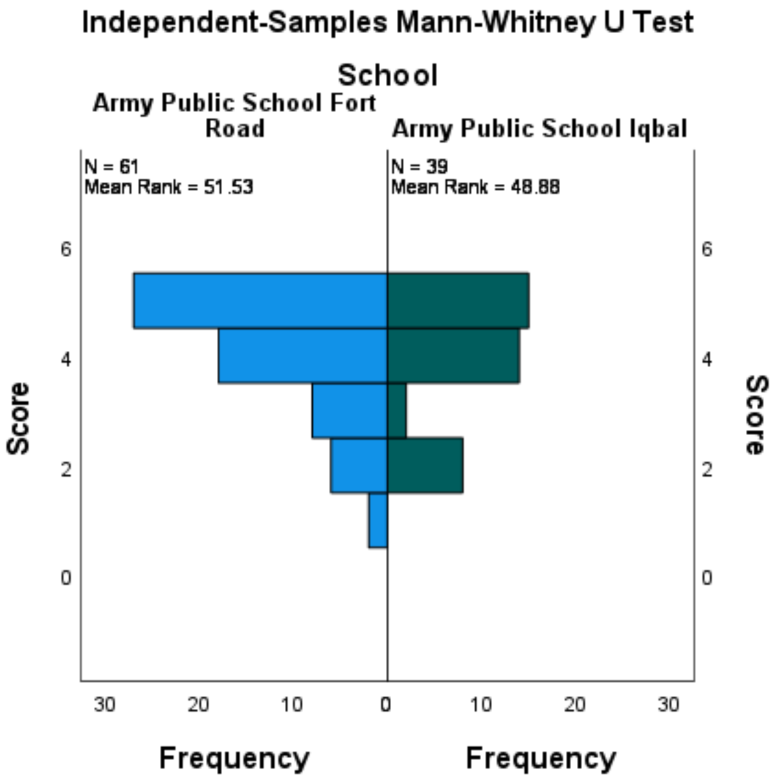


Figure 5.6: Mann-Whitney Test across Schools

- **Score across categories of Age**

A popular nonparametric test to compare outcomes among more than two independent groups is the Kruskal Wallis test. The Kruskal Wallis test is used to compare medians among k comparison groups ($k > 2$) and is sometimes described as an ANOVA with the data replaced by their ranks.

The Kruskal Wallis test was run on variable score across students aged 11-14 years to verify the following research hypotheses. Sample size was of 100 participants.

H_0: Marks obtained in post-test are equally high for students between ages 11-14 years.

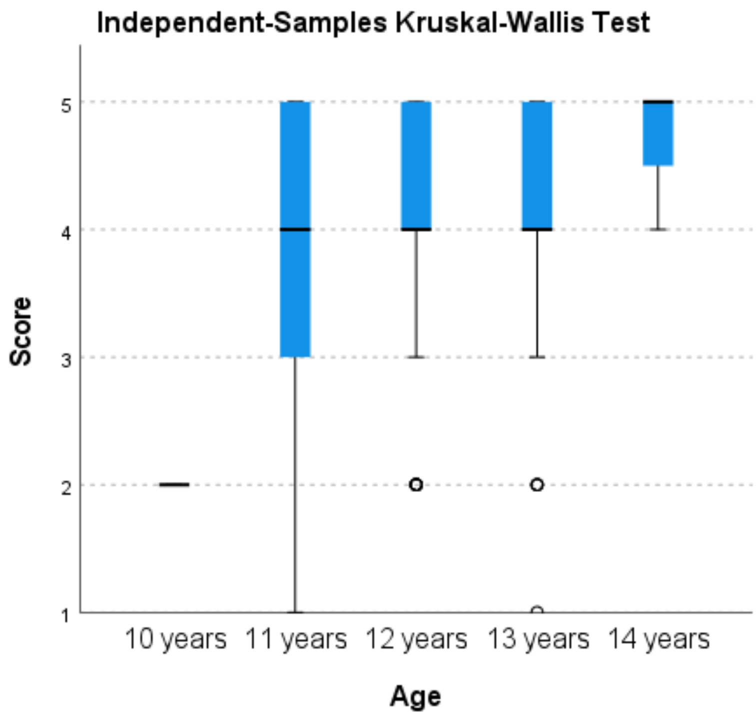
H_a: Marks obtained in post-test are not equally high for students between ages 11-14 years.

The null hypothesis was retained as result of statistical test. It was concluded that Marks obtained in post-test were equally high for all participant students between ages 11-14 years. Output of the test are listed in tables below.

Table 5.5: Kruskal-Wallis Test across Ages

Hypothesis Test Summary			
Null Hypothesis	**Test**	**Sig.[a,b]**	**Decision**
The distribution of Score is the same across categories of Age	Independent-Samples Kruskal-Wallis Test	.456	Retain the null hypothesis

Independent-Samples Kruskal-Wallis Test Summary	
Total N	100
Test Statistic	3.644a,b
Degree of Freedom	4
Asymptotic Sig.(2-sided test)	.456



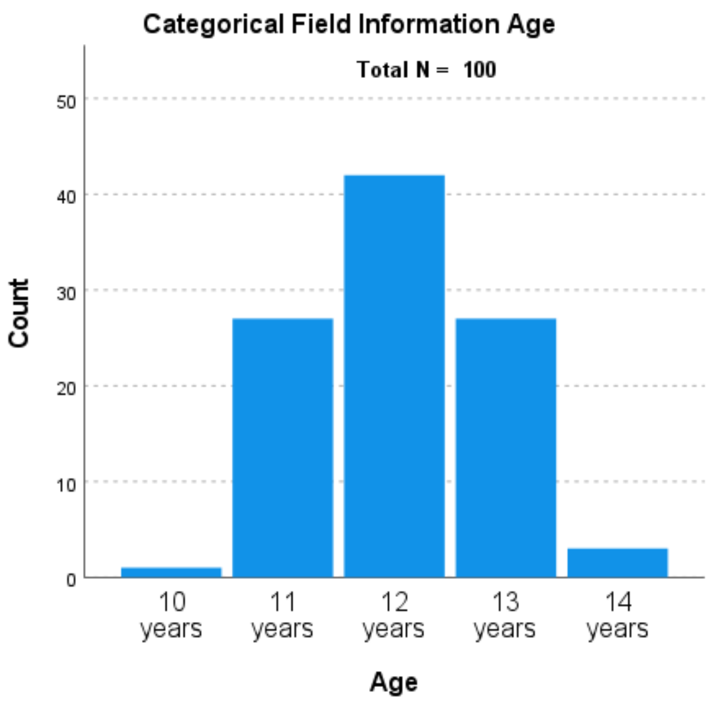


Figure 5.7: Kruskal-Wallis Test across Ages

- **Score across categories of Class**

Mann Whitney test was run on variable score across students of Grade 6 and Grade 7 to investigate differences in mean and verify the following hypotheses.

H_0: Marks obtained in post-test are equally high for students in Grade 6 and Grade 7.

H_a: Marks obtained in post-test are not equally high for students in Grade 6 and Grade 7.

The null hypothesis was retained as result of statistical test. It was concluded that Marks obtained in post-test were equally high for students in both Grades. Strength of student participants in Grade 6 were more than in Grade 7. Output of the test are listed in tables below.

Table 5.6: Mann-Whitney Test across Class

Hypothesis Test Summary			
Null Hypothesis	**Test**	**Sig.[a,b]**	**Decision**
The distribution of Score is the same across categories of Class	Independent-Samples Mann-Whitney U Test	.741	Retain the null hypothesis

Independent-Samples Mann-Whitney U Test Summary	
Total N	100
Mann-Whitney U	1287.000
Wilcoxon W	2368.000
Test Statistic	1287.000
Standard Error	136.369
Standardized Test Statistic	.330
Asymptotic Sig.(2-sided test)	.741

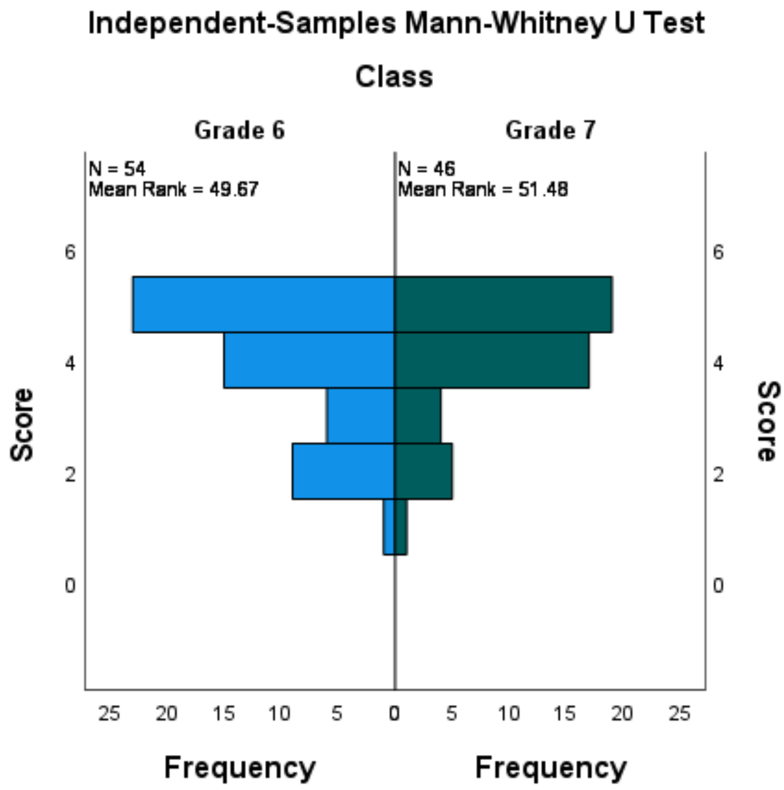


Figure 5.8: Mann-Whitney Test across Class

5.3. Summary

Data collected from control and experimental groups through post-tests (MCQ’s and Engagement surveys) was analysed to answer the research questions.

Higher engagement levels were depicted for experimental group as compared to control group. This data was analysed using graphical representation techniques.

For post-test MCQ’s, hypotheses were formulated and tested using statistical methods. Null hypothesis was rejected in this case i.e. Marks obtained in post-test are not equally high for playful and traditional methodology. It was analysed that participants in control group attained higher score in MCQ’s compared to experimental group.

6. Discussion

This research study was an attempt to compare playful pedagogy with traditional teaching methods in online learning during the lockdown period in COVID. The subject under study was STEM education using robotics. The content matter covered in the online lesson for both control and experimental groups was essentially the same. The difference was in the way the lesson was delivered. Robotics was part of the lesson for the experimental group only. The topic 'speed, distance and time' was taught to both the groups by the same instructor using traditional and playful pedagogy for control and experimental groups respectively.

Students of Grade 6 and 7 from Army Public Schools were chosen for the control and experimental groups with 50 participants in each group (total sample size N=100) and a Quasi-experimental study was conducted. The pedagogy differed for both the groups such that the control group was taught through traditional online learning whereas experimental group was immersed in discovery learning through play.

Designing a playful lesson plan takes more time than a traditional lesson plan as well as lesson delivery. The challenges and narrative building in playful learning demand more time and effort on behalf of the instructor for planning and execution. The lesson was mapped on 30 minutes; however, lesson delivery took more time for experimental group as compared to control group. The students in experimental group were more engaged during the lesson in challenges and discovery of the online robotics platform.

Introducing a new concept in class such as robotics requires the teacher to establish a connection with the students such that they develop familiarization with the concept instead of finding it foreign. This is important to maintain student engagement and interest during the lesson. For this study, robotics was introduced to the experimental group by relating robots with real life machines such as computers, televisions, automatic washing machines and microwaves etc. all these devices like robots require step-by-step instructions for execution of

commands. Building upon this foundation, it was easier for students to develop understanding of basic coding principles as they had to use block-based coding and program their robots in the online learning platform (vr.vex.com) to solve the challenges in their playful learning lesson.

To ensure un-biasness in the STEM lesson delivery, real-life examples were quoted during the lesson to both groups to keep the lesson STEM focused and achieve desired learning objectives.

As it is a challenge to keep the playful lesson structured, the teacher delivering the lesson focused on facilitating learners in play, offer feedback and guide learners to make discovery thereby ensuring that students do not de-track from lesson objective or lose engagement. In this case, it is also challenging to ensure that the student is learning through play and discovery and not being taught through transfer of knowledge from the teacher. For this reason, the teacher needs to be vigilant in offering timely feedback and optimum challenges which cater for diverse learner needs; as well as keep building the narrative upon requirement to keep the lesson playful and engaging.

6.1. Findings of the Study

The study was aimed to answer the following research questions by taking post-tests after implementation of research design from control and experimental groups to investigate results.

- **Research Question 1:** Incorporating playful learning in online STEM education through game design elements impacts learner's engagement?

The experimental group showed a substantial increase based on graphical representation techniques and there was a significant difference between the post-test engagement survey means of the control and experimental groups. This indicates the benefits of using playful learning in teaching STEM online through robotics.

Discussion

This answers our first research question. Hence, it is concluded that incorporating playful learning in online STEM education through game design elements impacts learner's engagement positively across affective, cognitive and behaviour domains.

- **Research Question 2:** Are learning outcomes achieved through online STEM?

After the online research implementation, post-test was conducted to assess learning of control and experimental groups. This post-test was MCQ based and taken through Google Forms. To analyse data, following hypotheses were formulated and tested using statistical methods.

H_0: Marks obtained in post-test are equally high for playful and traditional methodology.

H_a: Marks obtained in post-test are not equally high for both playful and traditional methodology.

It was analysed that the Null hypothesis was rejected for this study. There was a significant difference amongst the means of control and experimental groups across the variable score. It was investigated that participants in control group attained higher score in MCQ's compared to experimental group. Hence, we can conclude that, marks obtained in post-test are not equally high for playful and traditional methodology.

However, when the statistical tests were run across other variables to check whether score obtained had any relationship with school, age or the grade being taught, it was observed that these factors had not impacted marks of students and similar patterns of score were observed throughout all these variables. Difference in mean was only observed for control and experimental groups. Students being taught through traditional methodology scored higher marks in MCQ's.

6.1.1. Relationship of Learning with Scores

The research question for this study aimed to investigate whether learning outcomes were achieved by teaching STEM concepts online. In our hypotheses, we have related students' obtained marks in post-test with learning. However, marks may not be the most accurate means of assessing learning. It is difficult to assess the extent to which course assessments reflect student learning because valid measures of learning are not available (Beleche et al., 2012).

Testing can be reliable and valid, but it can measure only the inconsequential and distorted learning which is an unavoidable consequence of evaluation (Bryan & Clegg, 2006).

Research states that assessment and testing should be set apart. Assessment is an informal gathering of information about students' knowledge through various ways of collecting information at various times and in different contexts. Testing, however, is formal and standardized and offers students scoring on the tasks they have performed. Testing is a single-occasion and timed exercise which is considered as the only way through which student learning can be measured. Many scholars do not agree that there is a single method of gathering data concerning student learning. Testing therefore is seen as just one component of the broader concept of assessment (Kulieke et al., 1990).

Traditional assessment has emphasized on tests which show students' educational abilities. Research has pointed out the failure of traditional tests to capture the multi-dimensional aspects of what students have already learned (Mathies, 2000). According to learning scientists, subject matter content is easy to test but critical thinking and creativity is difficult to assess. Focus should be on long-term retention of knowledge and information and its transfer. Another method of assessment; Alternative assessment presents new ways of motivating and inspiring learners to explore and exploit dimensions of themselves as well as the world around them. Alternative assessment offers teachers a chance to realize their students' weaknesses and strengths in variant situations (Law & Eckes, 1995).

Similarly, authentic assessment involves students to carry out tasks which in one way or another involve them in some sort of problem-solving activities instead of testing rote learning and memorization. Authentic assessment puts forward a variant number of engaging tasks for the students in situations which are real world or simulation of real-world situations. As Wiggins (1990) claims, authentic assessment avails students with a wide range of skills and illuminates whether they have gained the ability to construct valid answers to the tasks presented. Moreover, he asserts that this kind of assessment sets a standardized criterion for scoring the tasks at hand by being highly reliable (Nasab, 2015).

In our research, since we cannot claim post-test to be authentic form of assessment, we cannot assume marks to be a true reflection of learning. As STEM is an interdisciplinary hands-on curriculum that aims to inculcate 21st century skills in learners, it cannot be tested by traditional assessment methods. The post-test for this research demanded students to answer multiple choice questions to assess their learning from the lesson being taught, this seems to be an inadequate method to assess learning and skills as it does not assess student performance.

In a performance assessment, rather than choosing among pre-determined options, students must construct an answer, produce a product, or perform a hands-on activity. Performance assessments allow students to construct or perform an original response rather than just recognizing a potentially right answer out of a list provided. Hence, performance assessments can measure students' cognitive thinking and reasoning skills as well as their ability to apply knowledge to solve realistic, meaningful problems (Darling-Hammond et al., 2010).

STEM education has received increasing attention in recent years. However, developing valid and reliable assessment of interdisciplinary learning in STEM is still a challenge. As STEM is interdisciplinary in nature, the connections across disciplines need to

be operationalized and properly assessed to provide targeted feedback to students. This demands further research and study. (Gao et al., 2020).

6.2. Limitations

The results of this quasi-experimental research study support the use of playful learning to teach STEM online by using robotics to increase student engagement. However, there are a few limitations to this study.

Firstly, due to time constraints, only the topic "Speed, distance and time" was taught to both control and experimental groups (the former through traditional learning approach and the latter through playful learning by using an online robotics platform). A more comprehensive study conducted in greater detail should include more topics so that a stronger conclusion about the benefits of playful learning in STEM education can be made.

Secondly, as the intervention was conducted during one lecture session (30 minutes), the implementation phase was very short. The lecture took more time to deliver for experimental group as compared to control group due to challenges and enhanced student engagement. However, the claim of playful learning advantages could be strengthened if the intervention was conducted for a longer period.

The pedagogy for experimental group was playful whereas assessment techniques were traditional. This was a huge limitation to this study. Further research is required to develop authentic assessment techniques for a playful lesson.

As the intervention was online due to COVID, technology was a must for both students and the teacher. High-speed internet and laptops were demanded specifically for students participating in experimental group as it was a requirement of the playful learning website. A limitation was that the website was not compatible with tablets or mobile phones whereas majority of student participants were using mobile phones to attend their online classes via MS Teams. List of students from APS Rawalpindi having desktops/ laptops at home was made by

conducting a pre-survey and only those students were made part of the experimental group. Students of APS Nowshera who were part of experimental group participated in the study by attending the class online from their school computer labs (when lockdown due to COVID eased) to minimize laptop/desktop requirement. For future studies, it is recommended that playful learning websites for education be developed for tablets and mobile phones so to bridge the current technology paradigm shift.

Another limitation was that the students participating in the study from both control and experimental groups were familiar with technology and already attending online classes. Being students of a renowned education system, Army Public Schools, the students were computer literate and quick at grasping new concepts including block-based coding in short time. So, it is safe to assume that their technological skills were polished to say the least. A similar study should be conducted with participants with average and low technological skills to investigate their performance and learning using an online robotics platform.

The integrated design framework has listed four types of engagement: affective, physical (behavioural), cognitive, and socio/cultural (Refer to Figure 3.1). For this study, we have not focused on role of socio/cultural engagement in playful learning. The post-tests have compared engagement levels of students of control and experimental groups in cognitive, affective, and behavioural domains but further study is needed to find out the factors which contribute to these multiple engagements resulting in playful learning as well as explore the role of socio/ cultural engagement.

7. Conclusion

The aim of this research was to overcome the challenge of incorporating playful learning in an online learning environment and explore factors that make STEM e-learning fun, engaging and effective, keeping the students intrinsically motivated. This study was undertaken due to scarcity of research available in this field and the increasing demand of effective online learning owing to the education disruption created by the COVID-19 pandemic.

The design framework implemented for this study is proposed by Jan L. Plass, Bruce D. Homer and Charles K. Kinzer. It describes the types of engagement created through game design elements to foster playful learning (Plass et al., 2014). These types include affective, cognitive, physical, and socio-cultural engagements. For this research, we have focused on studying the impact of affective, cognitive, and physical engagements of students created by the inclusion of game design elements in a playful online learning environment to teach a STEM topic.

A quasi experimental study was conducted and non-equivalent control group post-test only design was employed for this research. Students of Grade 6 and 7 from Army Public Schools of Rawalpindi and Nowshera were chosen for the control and experimental groups with 50 participants in each group (total sample size N=100). The lesson was conducted online via MS Teams since students had already been using MS Teams to attend their online classes during COVID lockdown and were familiar with its procedures. The topic 'speed, distance and time' was taught to both the groups by the same instructor using traditional and playful pedagogy for control and experimental groups respectively.

The control group was taught by their usual mode of lesson delivery. PowerPoint presentation was used to deliver the lesson to students in control group whereas, students in the experimental group were engaged in a playful learning experience by using an online robotics website (https://vr.vex.com). Students were given challenges to program their robots using

block-based coding. The website incorporated a Scratch like interface which facilitated ease of use for the students having no prior coding knowledge.

This research was designed to investigate whether playful learning techniques impacted learner's engagement and resulted in effective learning outcomes. The inclusion of game design elements; game mechanics, visual aesthetic design, narrative design, incentive system, content, and skills (Refer to Table 4.5) stimulated playful learning by using the robotics website to teach STEM concepts. Data was collected through post-tests after lesson delivery and analysed visually and statistically.

Higher engagement levels were depicted for experimental group as compared to control group. This data was analysed using graphical representation techniques. Whereas, to assess whether learning had occurred during the intervention, hypotheses were formulated and tested using statistical methods. In this case, our null hypothesis was rejected. It was concluded that participants in control group attained higher score in post-test MCQ's compared to experimental group.

To conclude this study, employing playful techniques enhances engagement levels in students, however; the purpose of using such techniques should aid traditional learning instead of replacing it entirely. Furthermore, playful assessment techniques that aim to gauge knowledge instead of testing rote memory and bookish curriculum need to be devised. The best combination would be to embed playful learning in existing curricula for effective and engaging learning to occur. One way to do that is by employing elements of game design for learning using an online robotics platform as represented through this research study.

Playful learning in online STEM still has a long way to go; needless to say, it helps create effective learning environments and benefits students. Learners stay intrinsically motivated by learning through online play that involves robotics. Coding principles help develop computational thinking in learners as well as build upon necessary 21st century skills.

Conclusion

It proves to be a fine alternative to classroom education in learning crises such as the recent pandemic hit. This research paves way for future studies in online STEM domain to explore and develop effective solutions that aid learning.

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Appendices

Appendix A

Post-test MCQ's

The post-test questionnaire to assess learning outcomes is given below.

Sr. no	Question	Correct Answer	Marks
1.	After a meal, an earthworm moves at a distance of 45 cm in 90 seconds. Find the speed of the earthworm. a) 2 cm/s b) 0.5 cm/s c) 4050 cm/s	0.5 cm/s	1
2.	A car travels at 88 km/hr over a distance of 22 km. Find the time taken for the car to travel this distance. a) 0.25 hours b) 1 hour c) 3 hours	0.25 hours	1
3.	A horse runs for 2 hours at a speed of 8 miles per hour. How far does it run? a) 16 miles b) 15 miles c) 16 kms	16 miles	1
4.	A car travelling at a steady speed takes 4 hours to travel 244 km. Find the speed of the car. a) 976 km/h b) 61 km/h c) 2 km/h	61 km/h	1
5.	A killer shark, attacking a fishing boat, swims at a speed of 13 m/s for half a minute. How far does it swim in this time? (Hint: half a minute = 30 sec) a) 390 m b) 6.5 m c) 0.43 m	390 m	1

Appendix B

Post-test Engagement Survey

The post-test survey to assess engagement levels of students is given below.

Sr. No	Prompt	Sub-factor	Response Options and Coding
1.	During this activity: I felt excited.	Affect	Very Much = 4 Yes = 3 Somewhat = 2 No = 1
2.	During this activity: I felt happy.	Affect	Very Much = 4 Yes = 3 Somewhat = 2 No = 1
3.	During this activity: I felt bored.	Affect	Very Much = 1 Yes = 2 Somewhat = 3 No = 4
4.	During this activity: I was daydreaming a lot.	Cognitive	Very Much = 1 Yes = 2 Somewhat = 3 No = 4
5.	During this activity: I was focused on the things we were learning most of the time.	Cognitive	Very Much = 4 Yes = 3 Somewhat = 2 No = 1
6.	During this activity: Time went by quickly.	Behaviour	Very Much = 4 Yes = 3 Somewhat = 2 No = 1
7.	During this activity: I was busy doing other tasks.	Behaviour	Very Much = 1 Yes = 2 Somewhat = 3 No = 4
8.	During this activity: I talked to others about stuff not related to what we were learning.	Behaviour	Very Much = 1 Yes = 2 Somewhat = 3 No = 4